Appendix F: Core Data Analysis

Problem statement: The spatial extent of the Aleutian Islands golden king crab (AIGKC) fishery has decreased markedly through time, but the current stock assessment model does not explicitly account for this change. The current exercise is an attempt to utilize only a subset of observer catch-per-unit-effort (CPUE) and (estimated) commercial fishery catch data that come from the same spatial extent (termed the "Core" fishing area) throughout the time series (1990–2015). Model runs were compared with Full dataset models (Scenarios 1 and 2) to examine the effects of decreasing fishing area over time.

METHODS

Creating the Core CPUE dataset (see Figs. F1, F2)

1) Reassigned all observer data currently used in AIGKC model lat/long from original dataset
    a. About 100 rows of data (pots) out of over 110K could not be reconciled.
    b. There are a number of pot locations (lat/long) that need to be error checked (e.g. show up on land)
2) Observer data (with lat/long) were plotted onto the GIS layer of 2X2 nm boxes.
    a. 2X2 boxes were created for Cooperative Survey design using 1990–2013 observer data
    b. 2X2 boxes were limited to:
        i. 100–1000m depth
        ii. Not on land
        iii. Only containing observer data with some catch (all size/sex classes of GKC); i.e., 2X2 boxes with observer data but no catch in any year were excluded and assumed to not be suitable GKC habitat.
    c. 2X2 boxes were decided on as a reasonable tradeoff between spatial resolution and fishing practices (e.g. strings of gear are 2–4 nm long).
        i. Sensitivity to box size should likely be considered (in progress).
3) 2X2 boxes were categorized as "Core" or "Non-Core" utilizing 2005–2013 observer data
    a. Core = area that had fishing effort and catch since rationalization
    b. Non-core = No effort in the area since rationalization.
4) Each row of observer data (1990–2015) was overlaid onto 2X2 boxes and categorized as:
    a. Core = Effort and Catch in the area since rationalization
    b. Non-core = No effort in the area since rationalization
    c. Other = Effort and Catch outside the 2X2 box layer due to:
        i. Errors in lat/long transcription
        ii. Effort but no catch in any year (i.e., assumed not GKC habitat)
        iii. Errors in bathymetry layer
        iv. Effort and Catch data from 2014–present
            1. Due to declining CPUE in WAG fishery started moving gear outside "Core" areas (e.g., AK Trojan to Bowers Ridge, and Early Dawn to Attu)
5) Observer data used in AIGKC model was then subset to only those data categorized as "Core"

Creating the Core Catch dataset

6) We assumed that observer coverage was proportional to total fishing effort in every year
    a. This needs to be vetted (though 100% observer coverage 1995/96-2004/05).
7) We assumed fishermen are equally skilled, or that fishermen are fishing proportionally in Core and non-core areas.
    a. If the least effective fishermen are fishing the less productive areas (i.e. Non-core) the ratio of Core:Non-core CPUE will be biased high and the estimate of catch inside the Core would be biased high (this would be more conservative).
8) For each year separately using the observer data, we calculated the ratio of Core:Non-Core CPUE and Effort
9) The product of these two ratios then let us estimate the ratio of Core Catch:Non-core Catch
10) The Catch ratio was then applied to overall Catch data used in the AIGKC model to estimate Catch within the Core area for each year (see algebra at the end).
    a. Catch in the model is separated by size classes; size frequencies were assumed to be the same for Core and Non-core areas.
11) These two “new” datasets only contain information from the same spatial extent throughout the history of the data (1990–2015) and are just a subset of the Full data set used in the current model.

Core Catch estimation:

Since total Catch (C_t) equals the product of *CPUE* and Effort (E), then the ratio of Catch in the Core (C_c) to Catch in the Non-Core (C_{nc}) area is:

$$\frac{C_{nc}}{C_c} = \frac{\left(\frac{C_{nc}}{E_{nc}}\right) \times E_{nc}}{\left(\frac{C_c}{E_c}\right) \times E_c}$$

where E_{nc} and E_c are the Effort in Core and Non-core areas, respectively.

Next, if:

$$\frac{C_{nc}}{C_c} = x$$

then:

$$C_{nc} = xC_c$$

And since:

$$C_t = C_{nc} + C_c$$

Then substituting for C_{nc}:

$$C_t = xC_c + C_c$$

And

$$C_t = (x + 1)C_c$$

And finally

$$C_c = \frac{C_t}{(x + 1)}$$

So we can estimate the catch in the Core area by having the total Catch (which is known) and the ratio of Catch in the Non-core and Core areas (which we can estimate).

Modeling

CPUE standardization methods were described in Appendix B. We applied those methods to Core data to determine CPUE indices for the periods 1995/96–2004/05 and 2005/06–2015/16. Because only observer data have the location details to separate the fishing area into finer cells (2X2nm), we restricted the time series to 1995/96–2015/16 for CPUE standardization and population model fitting. Therefore, the population model fitting results were compared with those for scenario 2 that ignores the fishery CPUE likelihood in the model fitting. However, for completeness, we included the base scenario (scenario 1) results as well.

RESULTS

Core area, CPUE, and catch estimates

The Core area represents approximately 30% of the total GKC habitat that was historically fished based on the 2X2nm boxes (similar for EAG and WAG). Of the 110,313 rows of observer data, 78,299 (71%) were categorized as Core, 28,441 (26%) as Non-core, and 3,573 (3%) as Other. Non-core and Other data were removed from the observer dataset and then only the Core data were used in the GLM for CPUE index determination.

Examining the observer data as a function of Core vs. Non-core areas prior to rationalization shows that on average 65% of the total effort came from Core areas (Fig. F3A, B) and the CPUE were on average 1.6 times greater in the Core than the Non-core areas (Fig. F3C, D) prior to rationalization. This suggests that approximately 74% of the total catch came from the Core areas (Fig F3E, F). Results are nearly identical for both the EAG and WAG. Total annual catch was then multiplied by the proportion of catch in the Core areas in each year to estimate Core catch and used in the population model fitting.

CPUE standardization of core data

The final models for EAG were:

$$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Gear} + \mathrm{Captain} + \mathrm{ns}(\mathrm{Soak}, 3) + \mathrm{Month} \quad \text{(F.1)}$$

for the 1995/96–2004/05 period [θ=1.34, $\mathrm{R}^2 = 0.2526$]

$$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{Gear} + \mathrm{ns}(\mathrm{Soak}, 11) \quad \text{(F.2)}$$

for the 2005/06–2015/16 period ($\theta = 2.29$, $\mathrm{R}^2 = 0.1207$).

The final models for WAG were:

$$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{ns}(\mathrm{Soak}, 15) + \mathrm{Gear} \quad \text{(F.3)}$$

for the 1995/96–2004/05 period [θ=1.04, $\mathrm{R}^2 = 0.1804$]

$$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Gear} + \mathrm{ns}(\mathrm{Soak}, 17) \quad \text{(F.4)}$$

for the 2005/06–2015/16 period [$\theta = 1.15$, $\mathrm{R}^2 = 0.0509, Soak\ forced\ in$].

For both the EAG and the WAG, the standardized CPUE showed a general increase whereas the non-standardized CPUE was relatively stable from 1995-2003. Post-rationalization showed almost no difference between CPUE indices (Figs. 4, 6). The (diagnostics) Q–Q plots of CPUE fitting appears satisfactory (Figs. 5, 7).

Model fitting

The core data were used for fitting the scenario 2 model (scenario 2 model is described in the main text and Appendix A). We used the Francis reweighting method to determine the updated weights for the length composition effective sample sizes. The Francis iteration results on core data are provided in Table F.1.

We provide the model fitted values for CPUE indices, Catches, F, and MMB (Figs. 8 to 15) for EAG and WAG.

The CPUE indices for the three models (Sc1, Sc2, and Sc2Core) were nearly identical except for slight divergence from 2011–2015 in the EAG, and from 2001–2004 in the WAG (Figs. 8, 9). The Core retained catches were well fitted by scenario Sc2Core but not by Sc1 or Sc2 in early years as expected due to the reduction of catch data in Sc2Core prior to rationalization (Figs. 10, 11). In the EAG, the overall (1960–2015) mature male biomass estimates were on average 20% lower using only Core data and catch estimates (i.e., Sc2Core) and were 15% lower since rationalization (2005–2015) compared with scenario

2 (full dataset) results. However, in the WAG, mature male biomass estimates were only 12% (overall) and 2% (post-rationalization) lower.

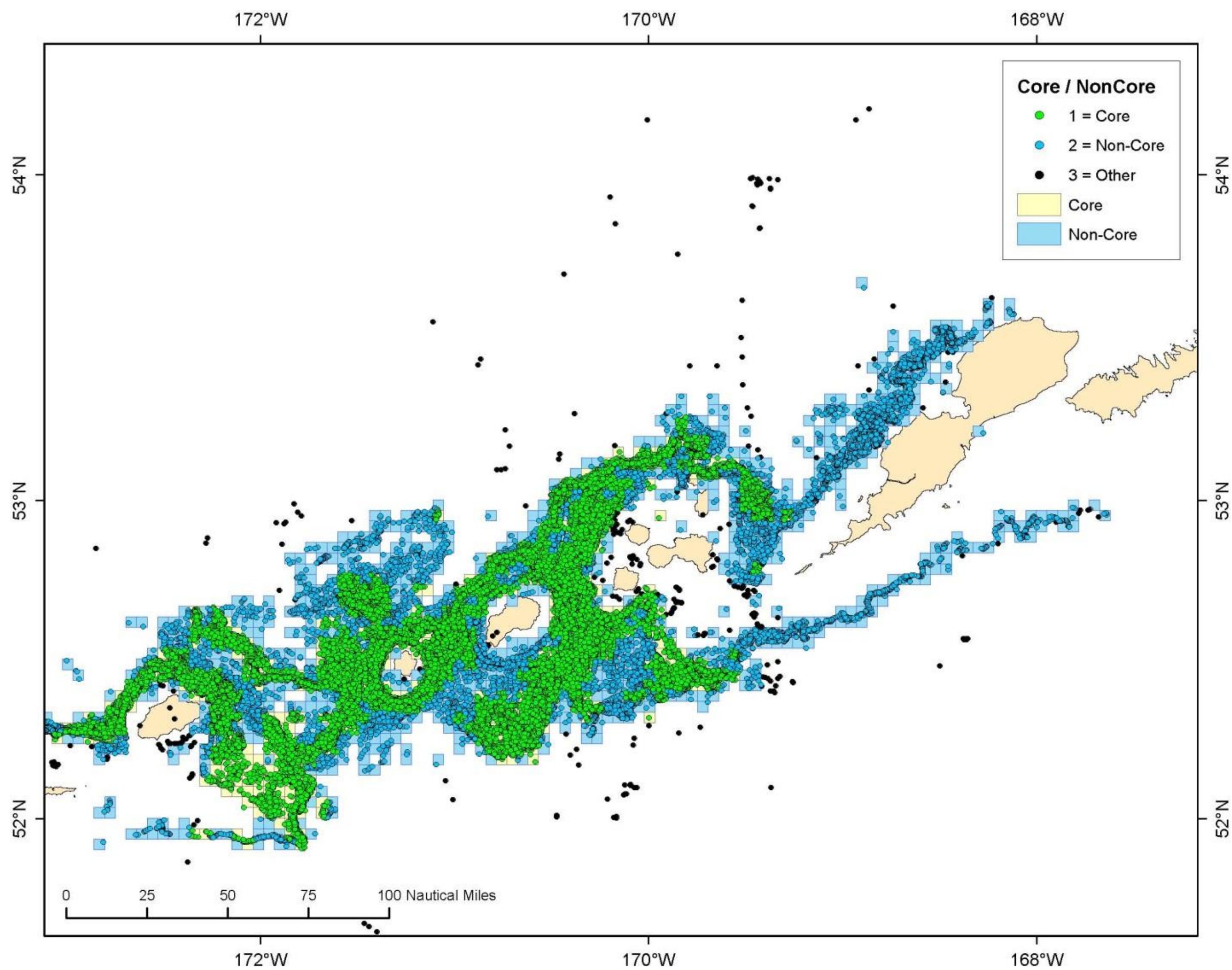


Figure F1. Map of EAG depicting Core areas (tan boxes; difficult to see under green dots) with associated observer data (green dots) and Non-core areas (blue boxes) and associated observer data (blue dots). Of the total 2012 2X2nm boxes, 588 (29%) are designated as Core and 1424 (71%) as Non-core.

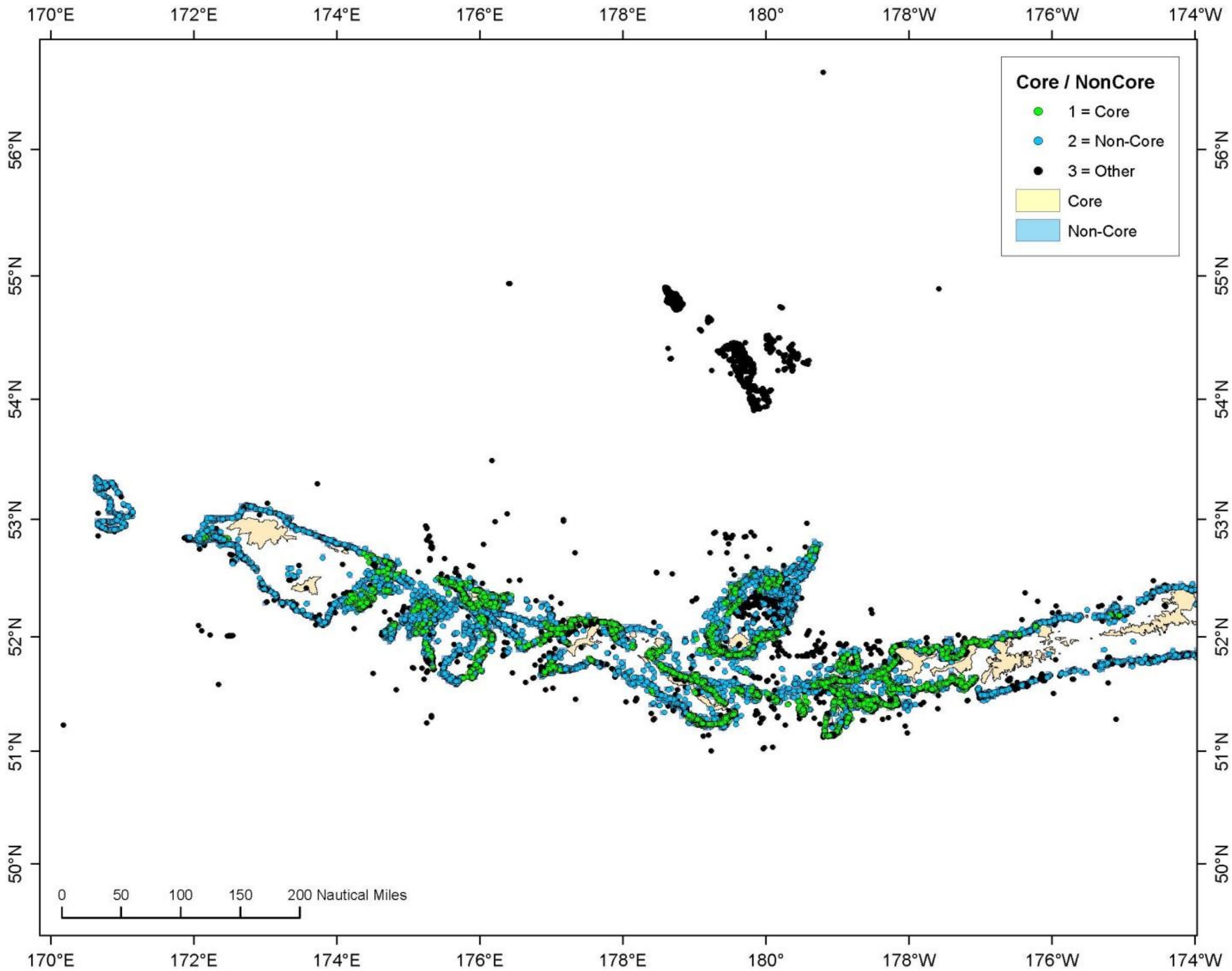


Figure F2. Map of WAG depicting Core areas (tan boxes; difficult to see under green dots) with associated observer data (green dots) and Non-core areas (blue boxes; difficult to see under blue dots) and associated observer data (blue dots). Of the total 2847 2X2nm boxes, 799 (28%) are designated as Core and 2048 (72%) as Non-core.

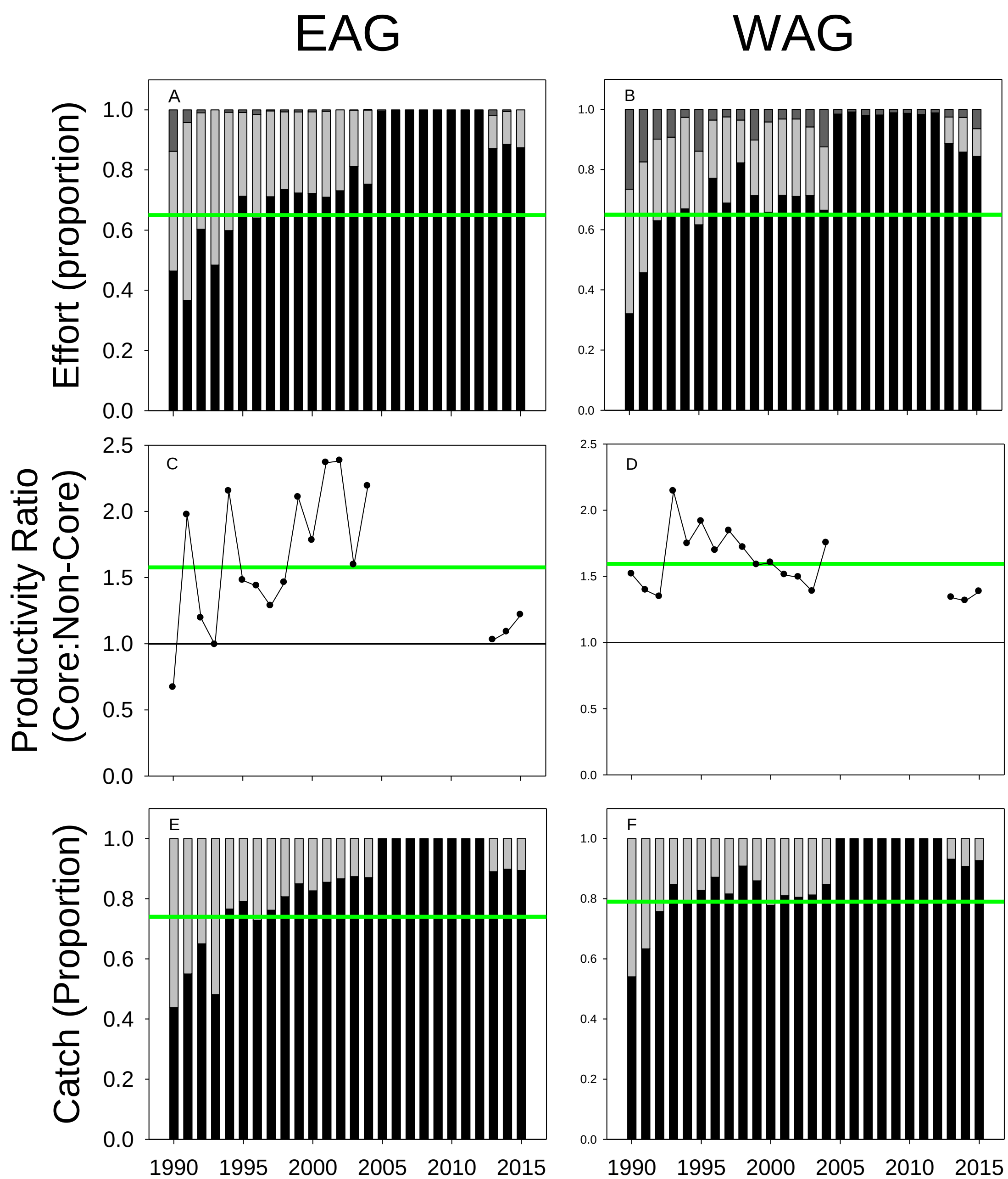
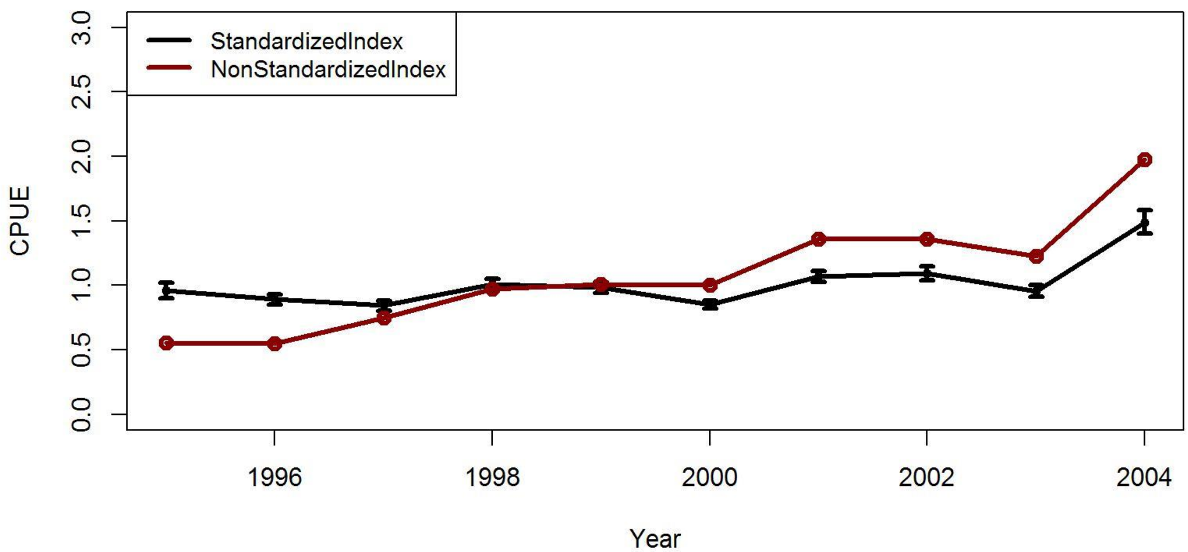


Figure F3. Effort (A, B), productivity (C, D), and Catch (E, F) from 1990–2015 in the EAG (A, C, E) and WAG (B, D, F). Effort is split into Core (black), Non-core (light grey), and Other (dark grey). Catch is split only into Core (black) and Non-core (light grey); Other catch could not be estimated. Green lines represent mean values for pre-rationalization time period (1990–2004).



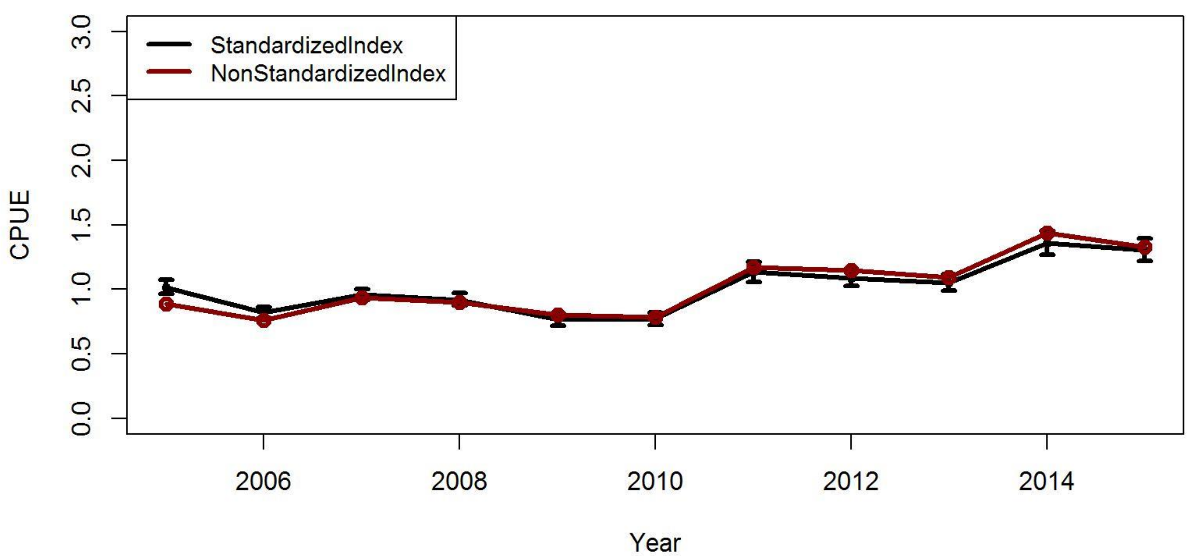


Figure F.4. Trends in non-standardized [arithmetic (nominal)] and standardized (negative binomial GLM) CPUE indices with +/- 2 SE for Aleutian Islands golden king crab observer core data from EAG (east of 174 ° W longitude). Top panel: 1995/96–2004/05 and bottom panel: 2005/06–2015/16. Standardized indices: black line and non-standardized indices: red line.

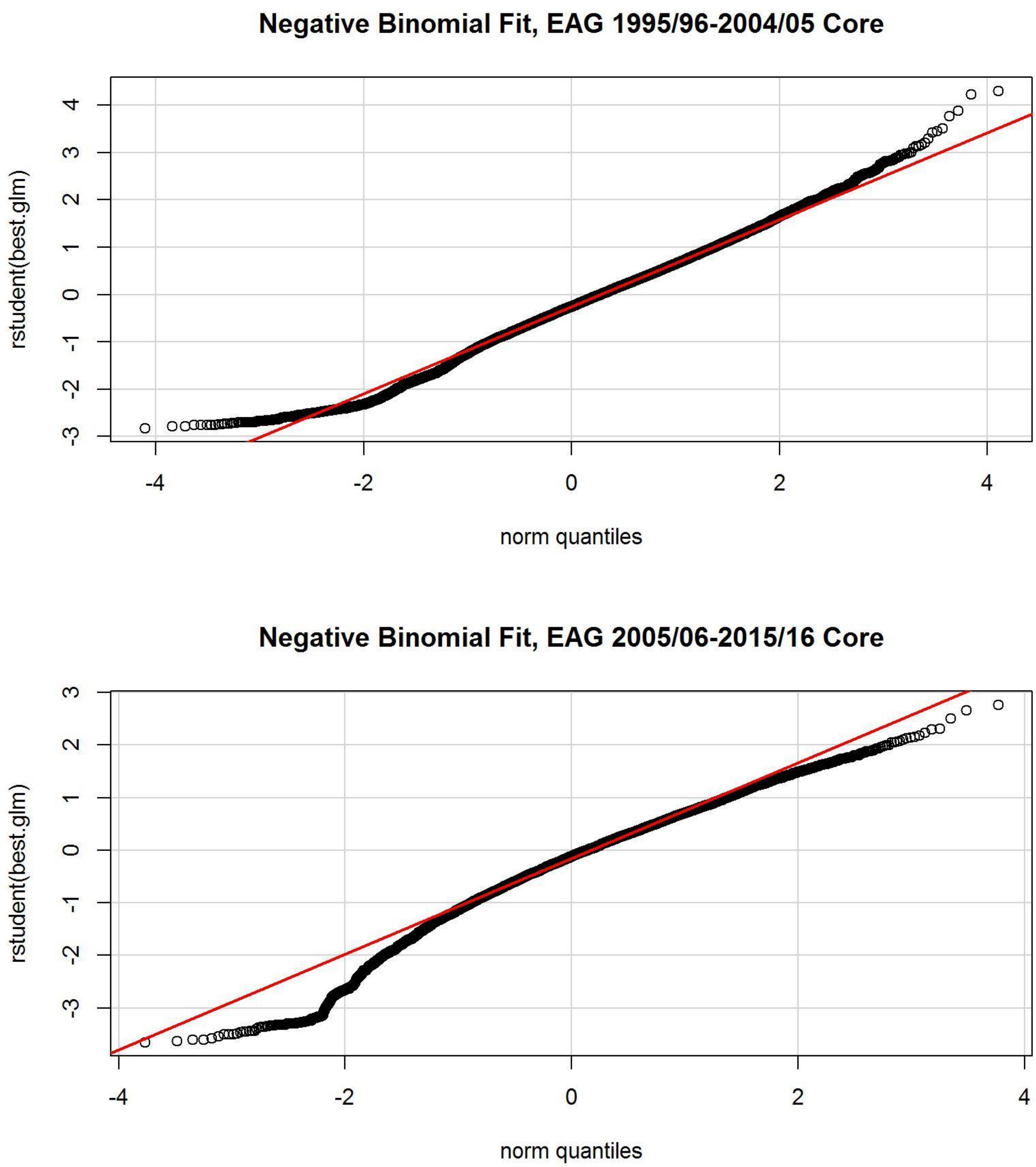


Figure F.5. Studentized residual plots for negative binomial GLM fit to EAG golden king crab observer core data for legal size male crab. Top panel is for 1995/96–2004/05 and bottom panel is for 2005/06–2015/16.

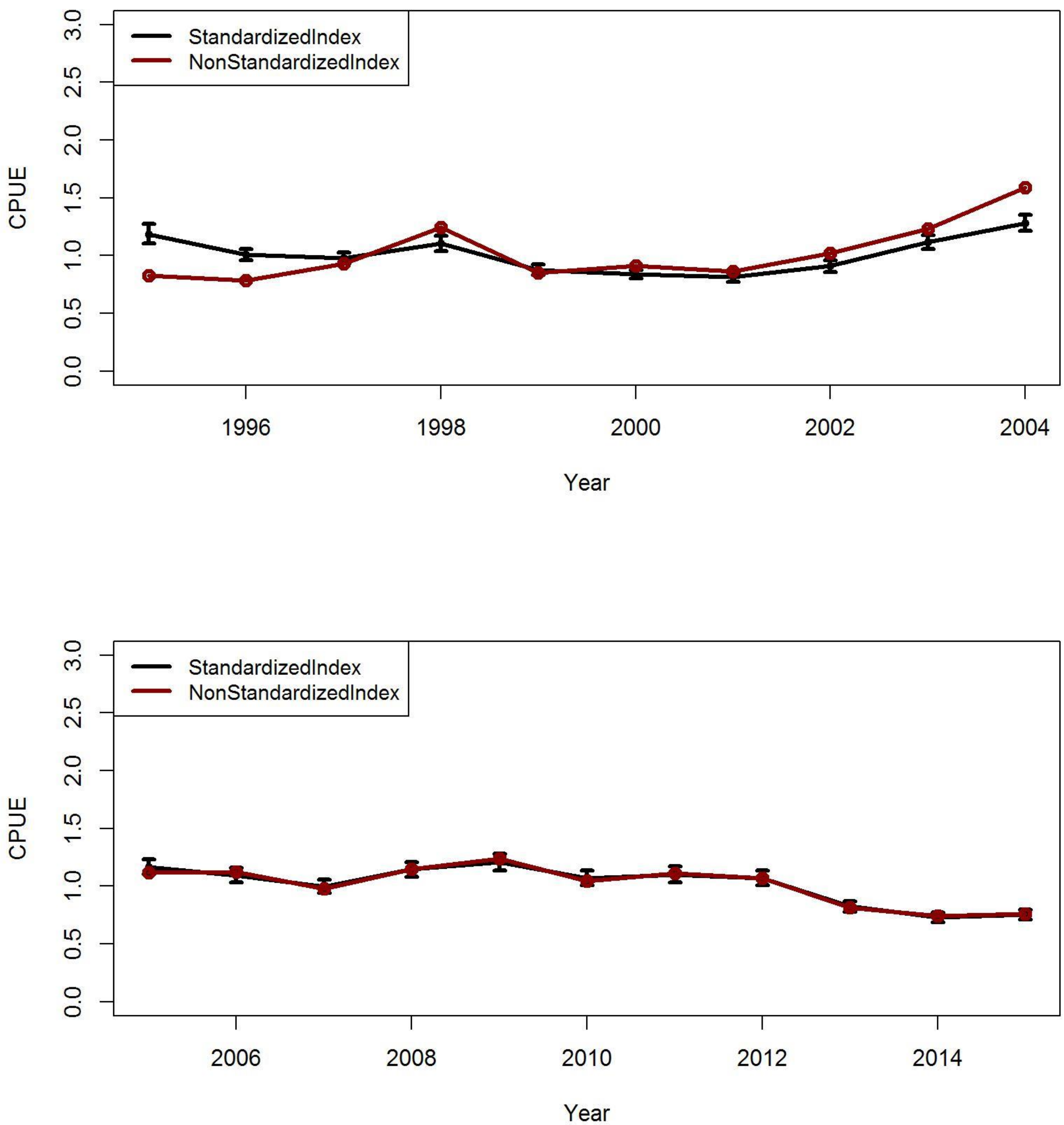


Figure F.6. Trends in non-standardized [arithmetic (nominal)] and standardized (negative binomial GLM) CPUE indices with +/- 2 SE for Aleutian Islands golden king crab observer core data from WAG (west of 174 ° W longitude). Top panel: 1995/96–2004/05 and bottom panel: 2005/06–2015/16. Standardized indices: black line and non-standardized indices: red line.

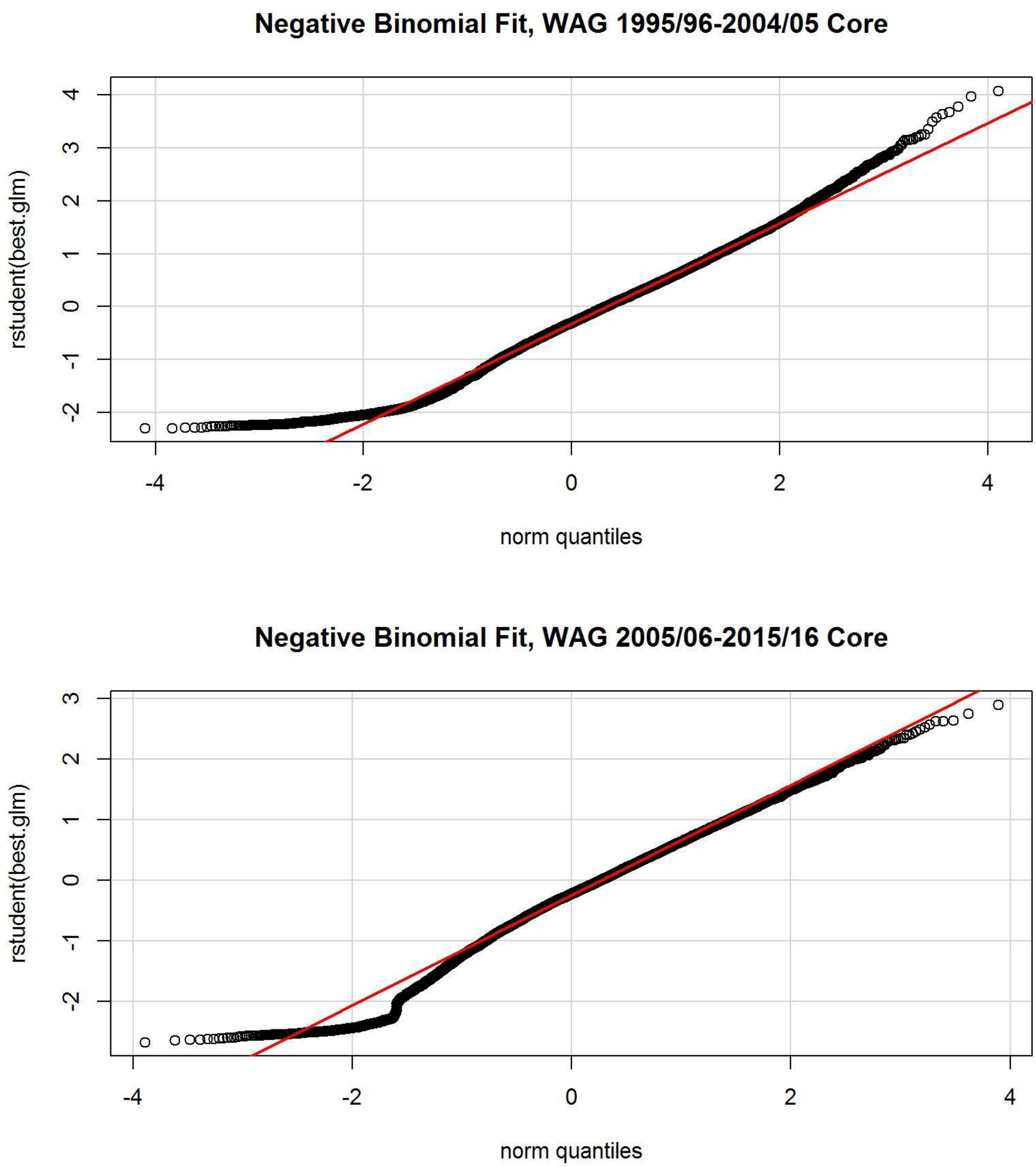


Figure F.7. Studentized residual plots for negative binomial GLM fit to WAG golden king crab observer core data for legal size male crab. Top panel is for 1995/96–2004/05 and bottom panel is for 2005/06–2015/16.

Table F.1. Iteration process for Stage-2 effective sample size reweighting multiplier, *W*, by Francis method for retained, total, and groundfish discard catch size compositions of golden king crab for scenario 2Core for EAG and WAG. The effective sample sizes are numbers of days for retained and total catch, but number of trips for groundfish discarded catch size compositions. Sc. =scenario. Note: For scenario 2Core, we have done more than six iterations to get the *W* and MMB converged, but we provide only the last three iteration results.

Area	Sc.	Iteration No.	Retained Catch Size Comp Effective Sample Multiplier (W)	Total Catch Size Comp Effective Sample Multiplier (W)	Groundfish Discard Catch Size Comp Effective Sample Multiplier (W)	Terminal MMB (t)	M yr^{-1}
EAG	2Core	1	0.8744	0.5161	0.4438	8,203	
		2	0.8739	0.5164	0.4438	8,203	
		3	0.8737	0.5165	0.4437	8,203	
WAG	2Core	1	0.4859	0.4388	0.7619	4,114	
		2	0.4861	0.4387	0.7619	4,115	
		3	0.4861	0.4386	0.7619	4,115	

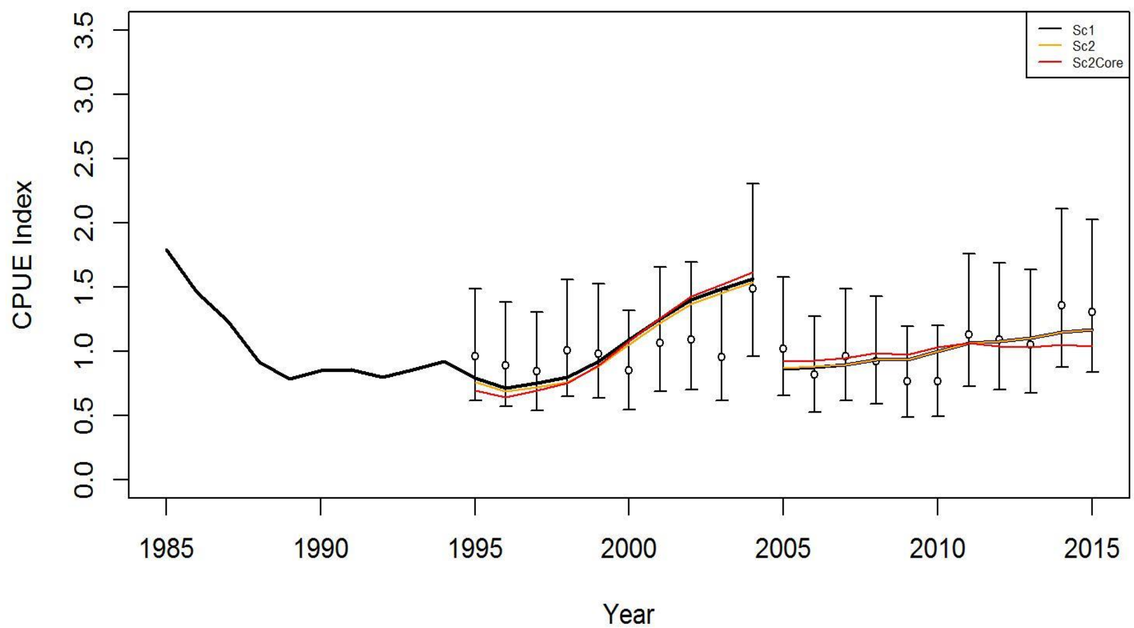


Figure F.8. Comparison of core data input CPUE indices (open circles with +/- 2 SE) with predicted CPUE indices (colored solid lines) under scenarios (Sc) 1, 2, and 2Core for EAG golden king crab data, 1985/86–2015/16. Model estimated additional standard error was added to each input standard error.

Note: low prediction of CPUE indices in recent years by scenario Sc2Core.

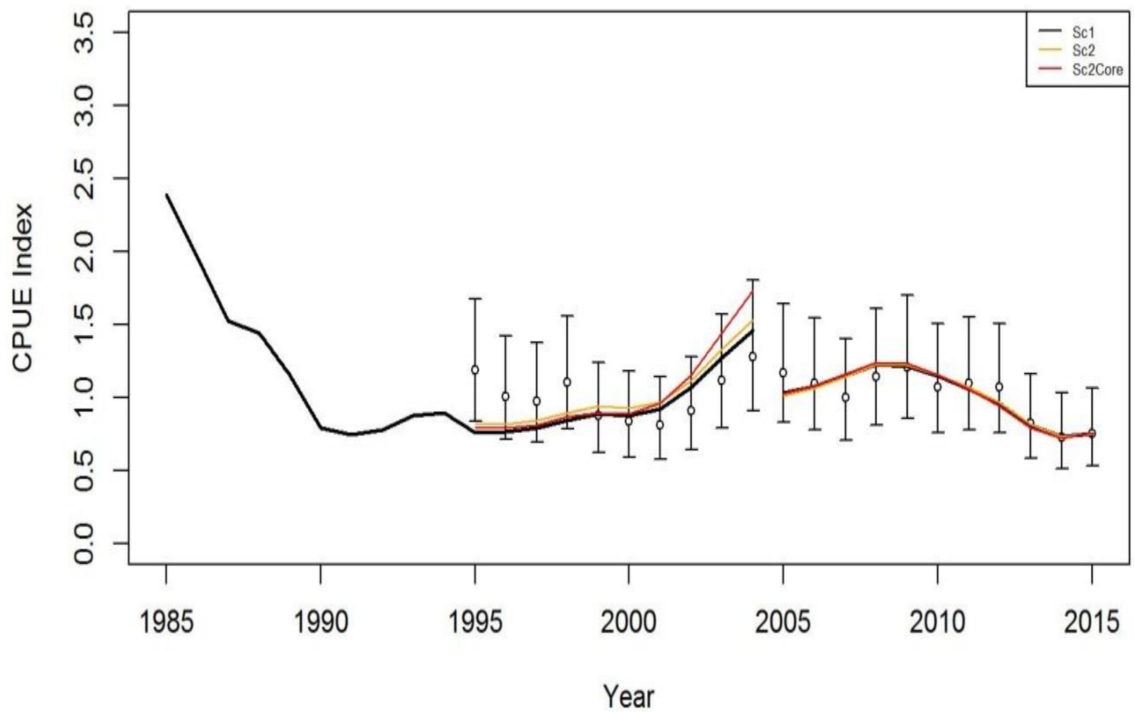


Figure F.9. Comparison of core data input CPUE indices (open circles with +/- 2 SE) with predicted CPUE indices (colored solid lines) under scenarios (Sc) 1, 2, and 2Core for WAG golden king crab data, 1985/86–2015/16. Model estimated additional standard error was added to each input standard error.

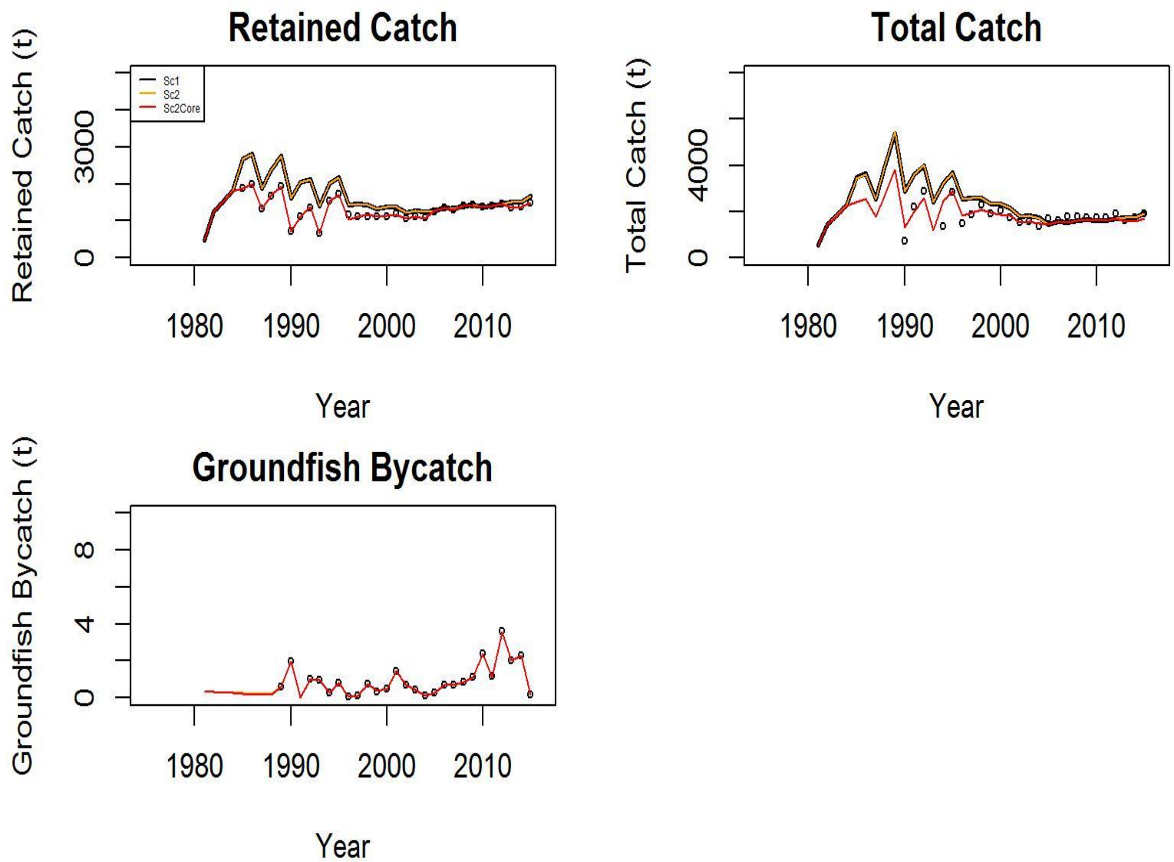


Figure F.10. Observed (open circle) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab for scenarios (Sc) 1 to 2Core data sets, in EAG, 1985–2015.

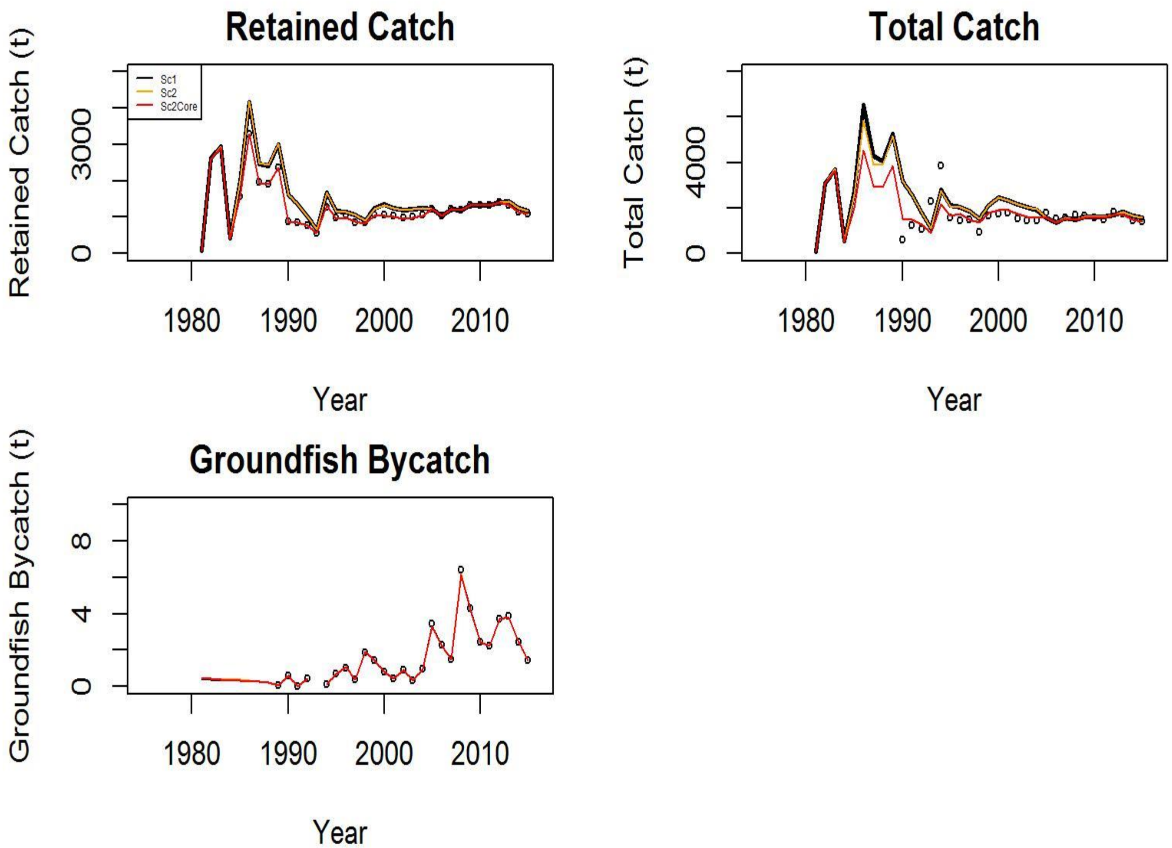


Figure F.11. Observed (open circle) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab for scenarios (Sc) 1 to 2Core data sets, in WAG, 1985–2015.

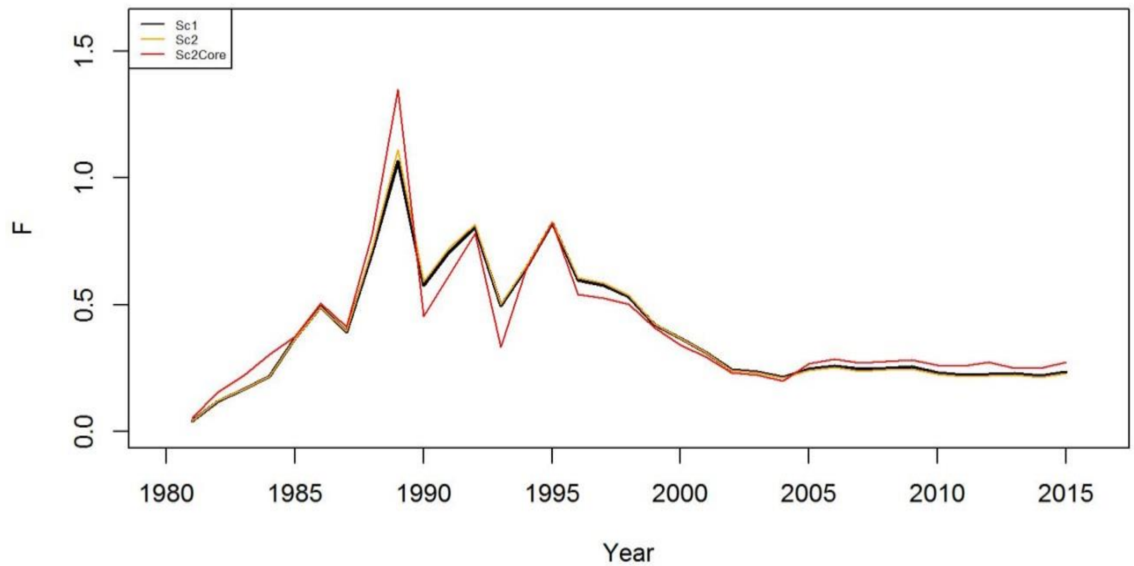


Figure F.12. Trends in pot fishery full selection total fishing mortality of golden king crab for scenarios (Sc) 1 to 2Core model fits in the EAG, 1981–2015.

Note: A little high prediction of F in recent years by scenario Sc2Core.

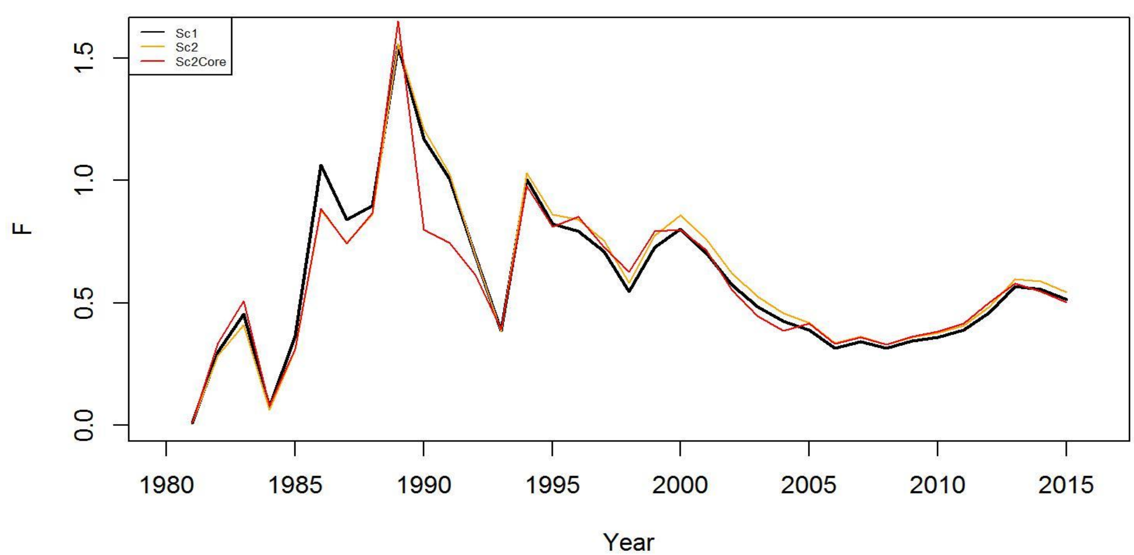


Figure F.13. Trends in pot fishery full selection total fishing mortality of golden king crab for scenarios (Sc) 1 to 2Core model fits in the WAG, 1981–2015.

Note: A little high prediction of F in recent years by scenario Sc2Core.

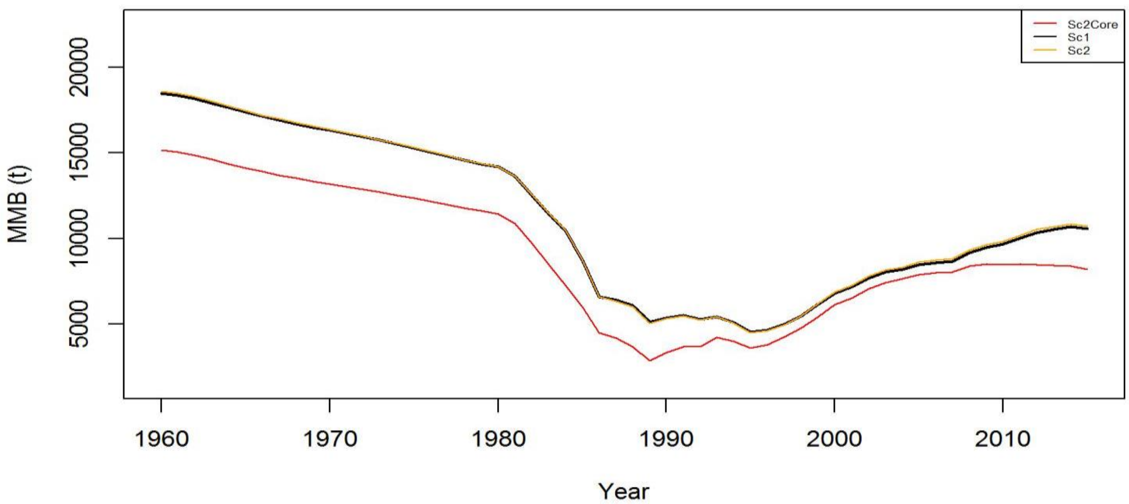


Figure F.14. Trends in golden king crab mature male biomass for scenarios (Sc) 1, 2, and 2Core fits in the EAG, 1960/61–2015/16.

Note: Low prediction of MMB by scenario Sc2Core throughout the time series.

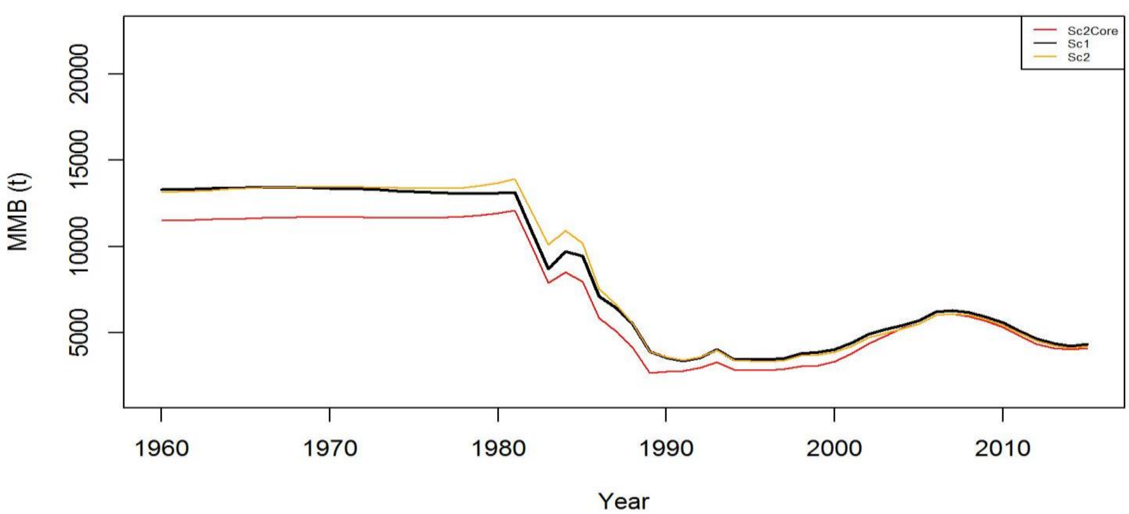


Figure F.15. Trends in golden king crab mature male biomass for scenarios (Sc) 1, 2, and 2Core fits in the WAG, 1960/61–2015/16.

Note: Low prediction of MMB by scenario Sc2Core throughout the time series.